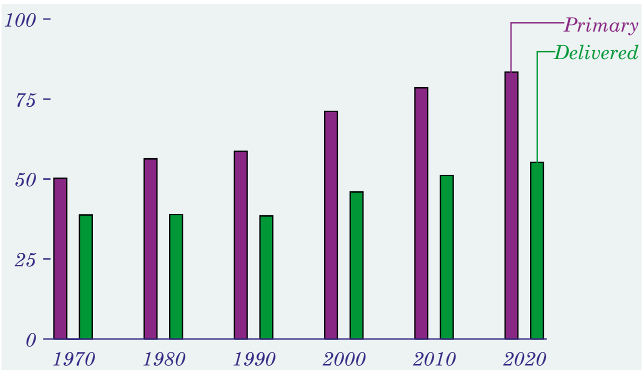
Annual Growth in Energy Use Is Projected To Continue

Figure 43. Primary and delivered energy consumption, excluding transportation use, 1970-2020 (quadrillion Btu)



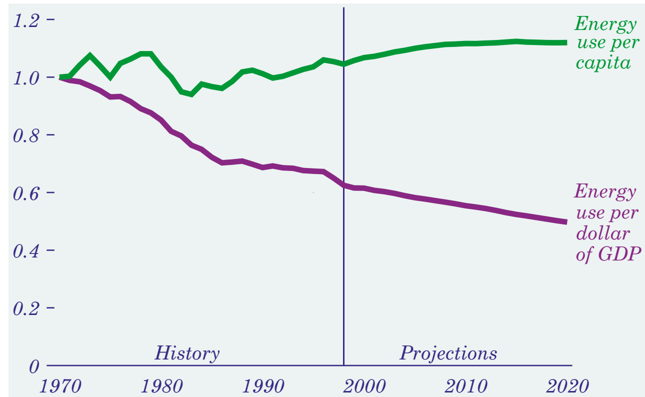
Net energy delivered to consumers represents only a part of total primary energy consumption. Primary consumption includes energy losses associated with the generation, transmission, and distribution of electricity, which are allocated to the end-use sectors (residential, commercial, and industrial) in proportion to each sector's share of electricity use [*57*].

How energy consumption is measured has become more important over time, as reliance on electricity has expanded. In 1970 electricity accounted for only 12 percent of energy delivered to the end-use sectors, excluding transportation. Since then, the growth in electricity use for applications such as space conditioning, consumer appliances, telecommunication equipment, and industrial machinery has resulted in greater divergence between total and delivered energy consumption (Figure 43). This trend is expected to stabilize in the forecast, as more efficient generating technologies offset increased demand for electricity. Projected primary energy consumption and delivered energy consumption grow by 0.9 percent and 1.0 percent a year, respectively, excluding transportation use.

At the end-use sectoral level, tracking of primary energy consumption is necessary to link specific policies with overall goals. Carbon emissions, for example, are closely correlated with total energy consumption. In the development of carbon stabilization policies, growth rates for primary energy consumption may be more important than those for delivered energy.

Average Energy Use per Person Shows Little Change in the Forecast

Figure 44. Energy use per capita and per dollar of gross domestic product, 1970-2020 (index, 1970 = 1)

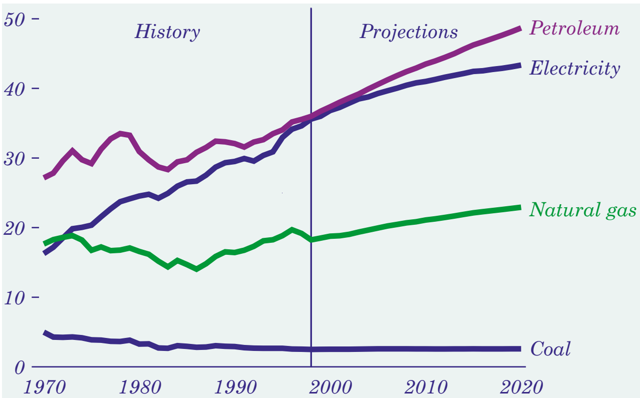


Energy intensity, both as measured by primary energy consumption per dollar of GDP and as measured on a per capita basis, declined between 1970 and the mid-1980s (Figure 44). Although the overall GDP-based energy intensity of the economy is projected to continue declining between 1998 and 2020, the decline is not expected to be as rapid as it was in the earlier period. GDP is estimated to increase by 61 percent between 1998 and 2020, compared with a 27-percent increase in primary energy use. Relatively stable energy prices are expected to slow the decline in energy intensity, as is increased use of electricity-based energy services. When electricity claims a greater share of energy use, consumption of primary energy per dollar of GDP declines at a slower rate, because electricity use contributes both end-use consumption and energy losses to total energy consumption.

In the *AEO2000* forecast, the demand for energy services increases markedly over 1998 levels. The average home in 2020 is expected to be 2 percent larger and to rely more heavily on electricity-based technologies. Annual highway travel and air travel per capita in 2020 are expected to be 21 percent and 97 percent higher, respectively, than in 1998. Nevertheless, despite the growth in demand for energy services, primary energy intensity on a per capita basis remains essentially static through 2020, with efficiency improvements in many end-use energy applications making it possible to provide higher levels of service without significant increases in total energy use per capita.

Petroleum Products Lead Growth in Energy Consumption

Figure 45. Primary energy use by fuel, 1970-2020 (quadrillion Btu)



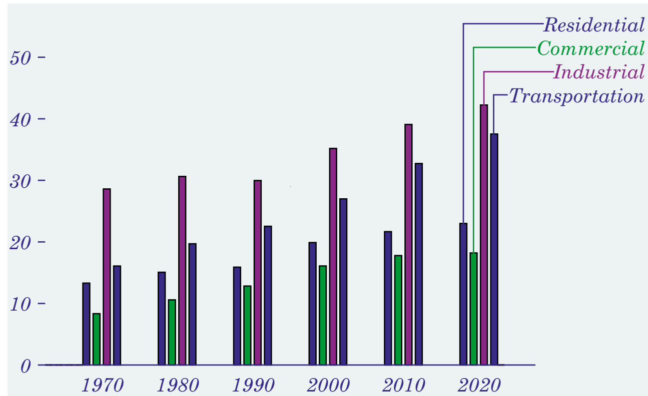
Consumption of petroleum products, mainly for transportation, claims the greatest share of primary energy use in the *AEO2000* forecast (Figure 45). Growth in energy demand in the transportation sector, which averaged 2.0 percent a year during the 1970s, was slowed in the 1980s by rising fuel prices and by new Federal vehicle efficiency standards, which led to an unprecedented 2.1-percent annual increase in average vehicle fuel economy. In the *AEO2000* forecast, fuel economy gains slow as a result of stable fuel prices and the absence of new legislative mandates. A growing population and increased travel per capita lead to increases in demand for gasoline throughout the forecast.

Increased competition and technological advances in electricity generation and distribution are expected to reduce the real cost of electricity. Despite low projected prices, however, growth in electricity use is slower than the rapid growth seen in the 1970s. Excluding consumption for electricity generation, demand for natural gas grows at a slightly slower rate than overall energy demand, in contrast to the recent trend of more rapid growth in the use of gas as the industry was deregulated. Natural gas is projected to meet 18.9 percent of all end-use energy requirements in 2020.

End-use demand for renewable energy from sources such as wood, wood wastes, and ethanol increases by 1.1 percent a year in the forecast. The use of geothermal and solar energy in buildings increases by about 3.8 percent a year but does not exceed 1 percent of energy consumption for space and water heating.

U.S. Primary Energy Use Exceeds 120 Quadrillion Btu a Year by 2020

Figure 46. Primary energy use by sector, 1970-2020 (quadrillion Btu)



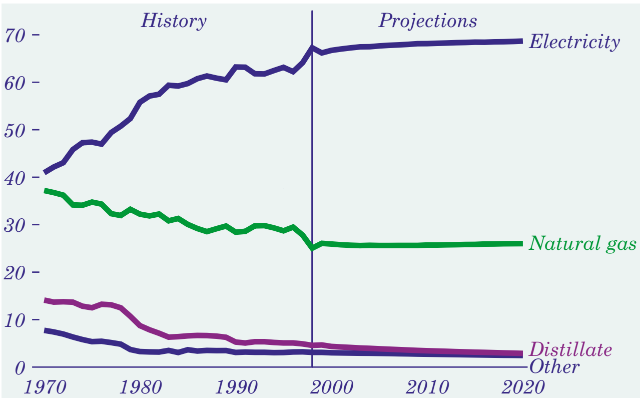
Primary energy use in the reference case is projected to exceed 120 quadrillion Btu by 2020, 27 percent higher than the 1998 level. In the early 1980s, as energy prices rose, sectoral energy consumption grew relatively little (Figure 46). Between 1985 and 1998, however, stable energy prices contributed to a marked increase in sectoral energy consumption.

In the forecast, energy demand in the residential and commercial sectors grows at about the same rate as population. Demand for energy in the transportation sector grows more rapidly, driven by estimates of increased per capita travel and slower fuel efficiency gains. Assumed efficiency gains in the industrial sector are projected to cause the demand for primary energy to grow more slowly than GDP.

To help bracket the uncertainty inherent in any long-term forecast, alternative assumptions were used to highlight the sensitivity of the *AEO2000* forecast to different oil price and economic growth paths. At the consumer level, oil prices primarily affect the demand for transportation fuels. Oil use for transportation in the high world oil price case is 4.2 percent lower than in the low world oil price case in 2020, as consumer choices favor more fuel-efficient vehicles and the demand for travel services is reduced slightly. In contrast, variations in economic growth assumptions lead to larger changes in the projections of overall energy demand in each of the end-use sectors [*58*]. For 2020, the projection of total annual energy use in the high economic growth case is 14 percent higher than in the low economic growth case.

Residential Energy Use Grows by More Than One-Fifth From 1998 to 2020

Figure 47. Residential primary energy consumption by fuel, 1970-2020 (percent of total)



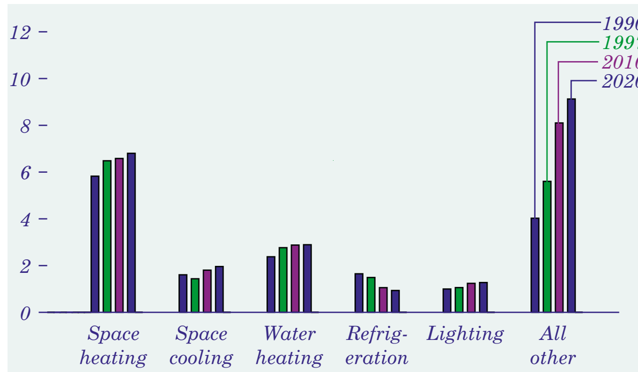
Residential energy consumption is projected to increase by more than 22 percent overall between 1998 and 2020. Most (74 percent) of the growth in total energy use is related to increased use of electricity. Sustained growth in housing in the South, where almost all new homes use central air conditioning, is an important component of the national trend, along with the penetration of consumer electronics, such as home office equipment and security systems (Figure 47).

While its share increases slightly, natural gas use in the residential sector is projected to grow by 1.1 percent a year through 2020. Natural gas prices to residential customers decline in the forecast and are lower than the prices of other fuels, such as heating oil. The number of homes heated by natural gas increases more than the number heated by electricity and oil. Petroleum use is projected to fall, with the number of homes using petroleum-based fuels for space heating applications expected to decrease over time.

Newly built homes are, on average, larger than the existing stock, with correspondingly greater needs for heating, cooling, and lighting. Under current building codes and appliance standards, however, energy use per square foot is typically lower for new construction than for the existing stock. Further reductions in residential energy use per square foot could result from additional gains in equipment efficiency and more stringent building codes, requiring more insulation, better windows, and more efficient building designs.

Efficiency Standards Should Moderate Residential Energy Use

Figure 48. Residential primary energy consumption by end use, 1990, 1997, 2010, and 2020 (quadrillion Btu)



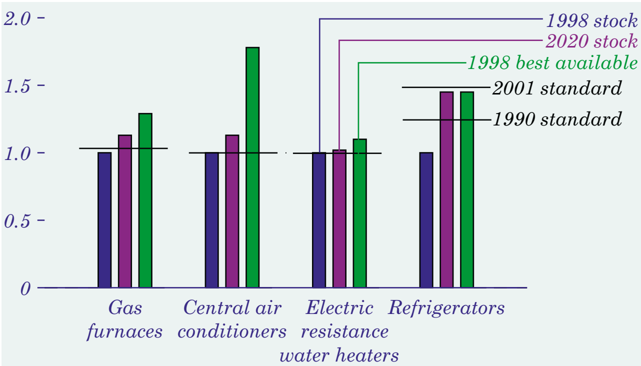
Energy use for space heating, the most energy-intensive end use in the residential sector, grew by 1.5 percent a year from 1990 to 1997 (Figure 48). Future growth should be slowed by higher equipment efficiency and tighter building codes. Building shell efficiency gains are projected to cut space heating demand in new homes by nearly 8 percent per household in 2020 relative to the demand in 1998.

A variety of appliances are now subject to minimum efficiency standards, including heat pumps, air conditioners, furnaces, refrigerators, and water heaters. Current standards for a typical residential refrigerator limit electricity use to 690 kilowatthours a year, and revised standards are expected to reduce consumption by another 30 percent by 2002. Energy use for refrigeration has declined by 1.4 percent a year from 1990 to 1997 and is expected to decline by about 2.0 percent a year through 2020, as older, less efficient refrigerators are replaced with newer models.

The "all other" category, which includes smaller appliances such as personal computers, dishwashers, clothes washers, and dryers, has grown by nearly 5 percent a year from 1990 to 1997 (Figure 48) and now accounts for 30 percent of residential primary energy use. It is projected to account for 40 percent in 2020, as small electric appliances continue to penetrate the market. The promotion of voluntary standards, both within and outside the appliance industry, is expected to forestall even larger increases. Even so, the "all other" category is expected to exceed other components of residential demand by 2020.

Available Technologies Can Slow Future Residential Energy Demand

Figure 49. Efficiency indicators for selected residential appliances, 1998 and 2020 (index, 1998 stock efficiency =1)

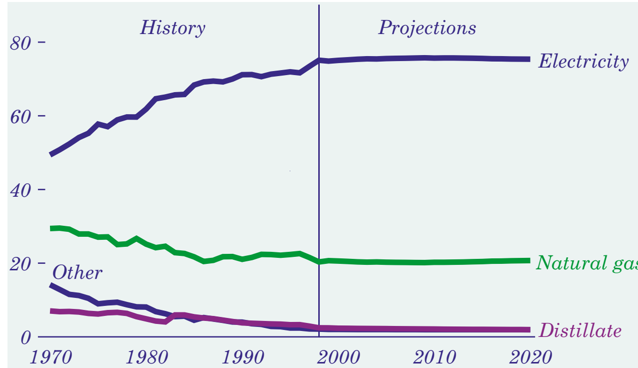


The *AEO2000* reference case projects an increase in the stock efficiency of residential appliances, as stock turnover and technology advances in most end-use services combine to reduce residential energy intensity over time. For most appliances covered by the National Appliance Energy Conservation Act of 1987, the most recent Federal efficiency standards are higher than the 1998 stock, ensuring an increase in stock efficiency (Figure 49) without any additional new standards. Future updates to the Federal standards could have a significant effect on residential energy consumption, but they are not included in the reference case. Proposed rules for new efficiency standards for water heaters are expected to be announced by June 2000, and several other product announcements are expected by spring 2001.

For almost all end-use services, technologies now exist that can significantly curtail future energy demand if they are purchased by consumers. The most efficient technologies can provide significant long-run savings in energy bills, but their higher purchase costs tend to restrict their market penetration. For example, condensing technology for natural gas furnaces, which reclaims heat from exhaust gases, can raise efficiency by more than 20 percent over the current standard; and variable-speed scroll compressors for air conditioners and refrigerators can increase their efficiency by 50 percent or more. In contrast, there is little room for efficiency improvements in electric resistance water heaters, because the technology is approaching its thermal limit.

Energy Fuel Shares for Commercial Users Are Expected To Remain Stable

Figure 50. Commercial nonrenewable primary energy consumption by fuel, 1970-2020 (percent of total)

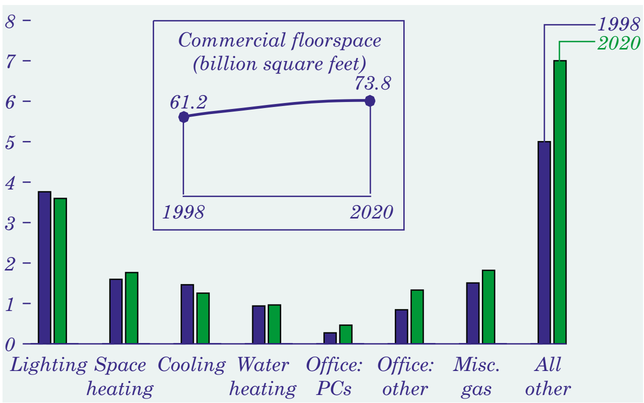


Projected energy use trends in the commercial sector show stable shares for all fuels, with growth in overall consumption slowing from its pace over the past two decades (Figure 50). Slow growth (0.8 percent a year) is expected in the commercial sector, for two reasons. Commercial floorspace is projected to grow by only 0.9 percent a year between 1998 and 2020, compared with an average of 1.5 percent a year over the past two decades. Lower growth in floorspace reflects the slowing labor force growth expected later in the forecast. Additionally, energy consumption per square foot is projected to decline by 0.1 percent a year, as a result of efficiency standards, voluntary government programs aimed at improving efficiency, and other technology improvements.

Electricity accounts for three-fourths of commercial primary energy consumption throughout the forecast. Expected efficiency gains in electric equipment are offset by continuing penetration of new technologies and greater use of office equipment. Natural gas accounts for 20 percent of commercial energy consumption in 1998 and maintains that share throughout the forecast. Distillate fuel oil makes up only 2 percent of commercial demand in 1998, down from 6 percent in the years before deregulation of the natural gas industry. The fuel share projected for distillate remains at 2 percent in 2020, as natural gas continues to compete for space and water heating uses. With stable prices projected for conventional fuels, no appreciable growth in the share of renewable energy in the commercial sector is anticipated.

Commercial Lighting Is the Sector's Most Important Energy Application

Figure 51. Commercial primary energy consumption by end use, 1998 and 2020 (quadrillion Btu)

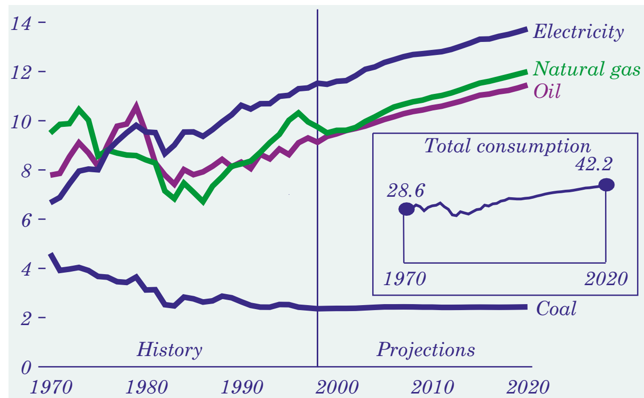


Through 2020, lighting remains the most important individual end use in the commercial sector [*59*]. Energy use for lighting declines slightly in the forecast as more energy-efficient lighting equipment and more efficient generating technologies are adopted. Efficiency also improves for space heating, space cooling, and water heating, moderating the growth in overall commercial sector energy demand. Increasing building shell efficiency, which affects the energy required for space heating and cooling, contributes to the trend (Figure 51).

The highest growth rates are expected for end uses that have not yet saturated the commercial market. Energy use for personal computers grows by 2.4 percent a year and for other office equipment, such as fax machines and copiers, by about 2.1 percent a year. The growth in electricity use for office equipment reflects a trend toward more powerful equipment, the response to a projected decline in real electricity prices, and an increase in the market for commercial electronic equipment. Natural gas use for such miscellaneous uses as cooking, district heating, and self-generated electricity is expected to grow by 0.9 percent a year. New telecommunications technologies and medical imaging equipment increase electricity demand in the "all other" end use category, which also includes ventilation, refrigeration, minor fuel consumption, service station equipment, and vending machines. Growth in the "all other" category is expected to slow somewhat in later years of the projection period, as emerging technologies achieve greater market penetration.

Industrial Energy Use Could Grow by More Than 20 Percent by 2020

Figure 52. Industrial primary energy consumption by fuel, 1970-2020 (quadrillion Btu)

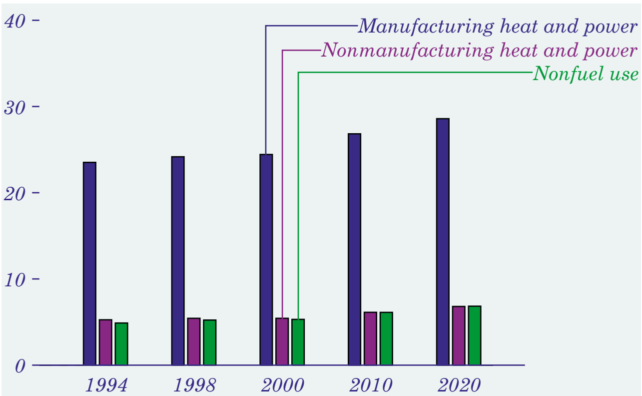


From 1970 to 1986, with demand for coking coal reduced by declines in steel production and natural gas use falling as a result of end-use restrictions and curtailments, electricity's share of industrial energy use increased from 23 percent to 35 percent. The natural gas share fell from 33 percent to 25 percent, and coal's share fell from 16 percent to 10 percent. After 1986, natural gas began to recover its share as end-use regulations were lifted and supplies became more certain and less costly. The *AEO2000* projections of plentiful supplies and relatively stable prices allow natural gas to maintain its current share of industrial energy consumption while electricity's share of delivered energy increases slightly.

Primary energy use in the industrial sector—which includes the agriculture, mining, and construction industries in addition to traditional manufacturing—increases by 0.9 percent a year in the forecast (Figure 52). Electricity (for machine drive and some production processes) and natural gas (given its ease of handling) are the major energy sources for the industrial sector. Industrial delivered electricity use is projected to increase by 31.7 percent, as competition in the generation market keeps electricity prices low. Relatively low prices are also projected for natural gas, resulting in consumption that is 23.0 percent over its 1998 level by 2020. Industrial petroleum use grows by 25.4 percent over the same period. Coal use increases slowly, by 0.1 percent a year, as new steelmaking technologies continue to reduce demand for metallurgical coal, offsetting the modest growth in coal use for boiler fuel and as a substitute for coke in traditional steelmaking.

Industrial Energy Use Grows Steadily in the Projections

Figure 53. Industrial primary energy consumption by industry category, 1994-2020 (quadrillion Btu)



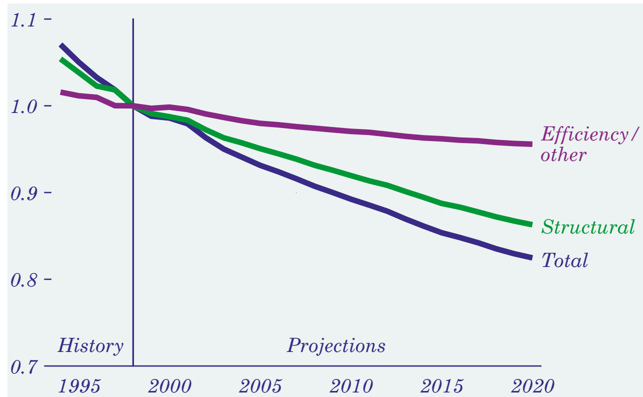
More than two-thirds of all the energy consumed in the industrial sector is used to provide heat and power for manufacturing; the remainder is approximately equally distributed between nonmanufacturing heat and power and consumption for nonfuel purposes, such as raw materials and asphalt (Figure 53).

Nonfuel use of energy grows more rapidly (1.2 percent annually) than does projected heat and power consumption (0.8 percent annually). The feedstock portion of nonfuel use is projected to grow at the same rate as the bulk chemical industry (1.1 percent annually) due to limited substitution possibilities. In 2020, feedstock consumption is projected to be 5.0 quadrillion Btu. Asphalt, the other component of nonfuel use, is projected to grow by 1.6 percent a year, to 1.8 quadrillion Btu in 2020. The growth rate for asphalt use is slightly less than the projected annual growth rate for the construction industry (1.7 percent), which is the principal consumer of asphalt for paving and roofing.

Petroleum refining, chemicals, and pulp and paper are the largest end-use consumers of energy for heat and power in the manufacturing sector. These three energy-intensive industries used 8.9 quadrillion Btu in 1998. The major fuels used in petroleum refineries are still gas, natural gas, and petroleum coke. In the chemical industry, natural gas accounts for two-thirds of the energy consumed for heat and power. The pulp and paper industry uses the most renewables, in the form of wood and spent liquor.

Output From U.S. Industries Grows Faster Than Energy Use

Figure 54. Industrial delivered energy intensity by component, 1994-2020 (index, 1998 = 1)

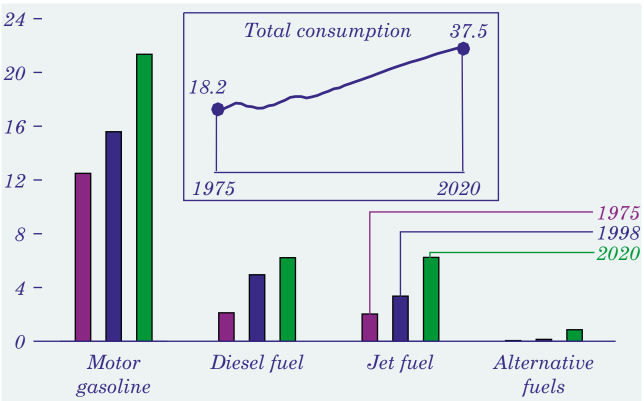


Changes in industrial energy intensity (consumption per unit of output) can be separated into two effects. One component reflects underlying increases in equipment and production efficiencies; the other arises from structural changes in the composition of manufacturing output. Since 1970, the use of more energy-efficient technologies, combined with relatively low growth in the energy-intensive industries, has dampened growth in industrial energy consumption. Thus, despite a 50-percent increase in industrial output, total energy use in the sector grew by only 12 percent between 1977 and 1998. These basic trends are expected to continue.

The share of total industrial output attributed to the energy-intensive industries is projected to fall from 23 percent to 19 percent from 1998 to 2020. Thus, even if no specific industry experienced a decline in intensity, aggregate industrial intensity would decline. Figure 54 shows projected changes in energy intensity due to structural effects and efficiency effects separately [*60*]. Over the forecast period, industrial delivered energy intensity drops by 17 percent, and the changing composition of industrial output alone results in approximately a 13-percent drop. Thus, more than two-thirds of the change in delivered energy intensity for the sector is attributable to structural shifts and the remainder to changes in energy intensity associated with increases in equipment and production efficiencies.

Alternative Fuels Make Up 4 Percent of Light-Duty Vehicle Fuel Use in 2020

Figure 55. Transportation energy consumption by fuel, 1975, 1998, and 2020 (quadrillion Btu)



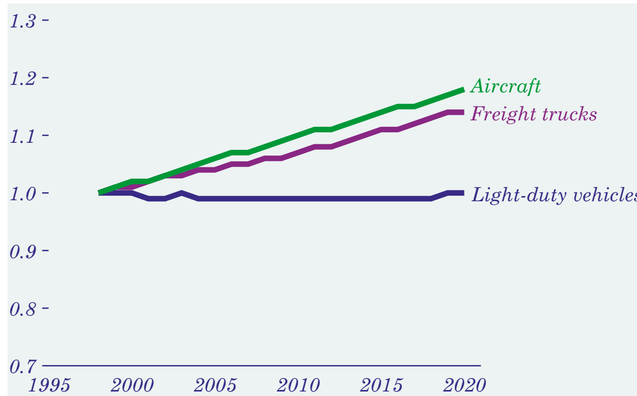
By 2020, total energy demand for transportation is expected to be 37.5 quadrillion Btu, compared with 25.9 quadrillion Btu in 1998 (Figure 55). Petroleum products dominate energy use in the sector. Motor gasoline use, increasing by 1.4 percent a year in the reference case, makes up more than half of transportation energy demand. Alternative fuels are projected to displace about 406,000 barrels of oil equivalent a day [*61*] by 2020 (about 4 percent of light-duty vehicle fuel consumption), in response to current environmental and energy legislation intended to reduce oil use. Gasoline's share of demand is sustained, however, by low projected gasoline prices and by slower fuel efficiency gains for conventional light-duty vehicles (cars, vans, pickup trucks, and sport utility vehicles) than were achieved during the 1980s.

Assumed industrial output growth of 1.8 percent a year through 2020 leads to an increase in freight transport, with a corresponding 1.0-percent annual increase in diesel fuel use. Economic growth and low projected jet fuel prices yield a 4.0-percent annual increase in air travel, causing jet fuel use to increase by 2.9 percent a year.

In the forecast, energy prices directly affect the level of oil use through travel costs and average vehicle fuel efficiency. Most of the projected price sensitivity is seen as variations in motor gasoline use in light-duty vehicles, because the stock of light-duty vehicles turns over more rapidly than the stock for other modes of travel. In the high oil price case, gasoline use increases by only 1.3 percent a year, compared with 1.6 percent a year in the low oil price case.

Average Horsepower for New Cars Is Projected To Grow by 30 Percent

Figure 56. Transportation stock fuel efficiency by mode, 1998-2020 (index, 1998 = 1)



Fuel efficiency improves at a slower rate through 2020 than it did in the 1980s (Figure 56), with fuel efficiency standards for light-duty vehicles assumed to stay at current levels. Projected low fuel prices and higher personal income increase the demand for larger, more powerful vehicles. Average horsepower for new cars in 2020 is about 30 percent above the 1998 level (Table 8), but the use of advanced technologies and materials keeps new vehicle fuel economy from declining. New advanced technologies, such as gasoline fuel cells and direct fuel injection and electric hybrids for both gasoline and diesel engines, are projected to boost fuel economy levels gradually through 2020, by about 1 to 2 miles per gallon.

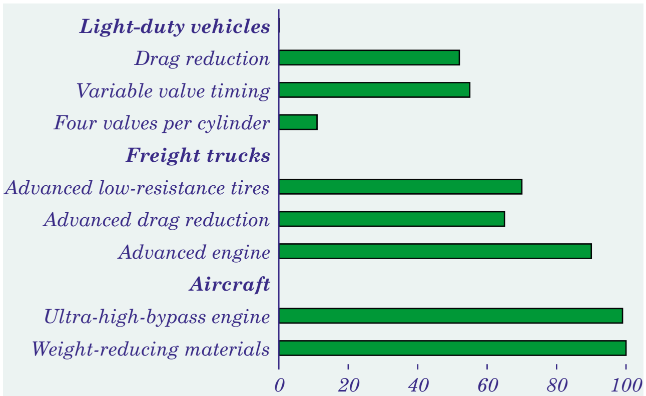
From 1990 to 1998, the horsepower of compact sport utility vehicles (medium light trucks) increased slightly faster than that of standard sport utility vehicles (large light trucks)—3.2 percent vs. 3.1 percent a year [*62*]. If it continues, this trend will lead to slightly higher horsepower for medium than for large light trucks by 2020.

Table 8. New car and light truck horsepower ratings and market shares, 1990-2020

	Cars			Light trucks		
Year	Small	Medium	Large	Small	Medium	Large
1990						
Horsepower	118	141	164	132	165	175
Sales share	0.60	0.28	0.12	0.50	0.38	0.12
1998						
Horsepower	164	193	208	191	213	224
Sales share	0.54	0.34	0.12	0.36	0.52	0.12
2010						
Horsepower	176	211	262	226	271	262
Sales share	0.56	0.31	0.13	0.33	0.50	0.16
2020						
Horsepower	211	246	298	274	307	304
Sales share	0.55	0.31	0.14	0.34	0.53	0.13

New Technologies Promise Better Vehicle Fuel Efficiency

Figure 57. Technology penetration by mode of travel, 2020 (percent)



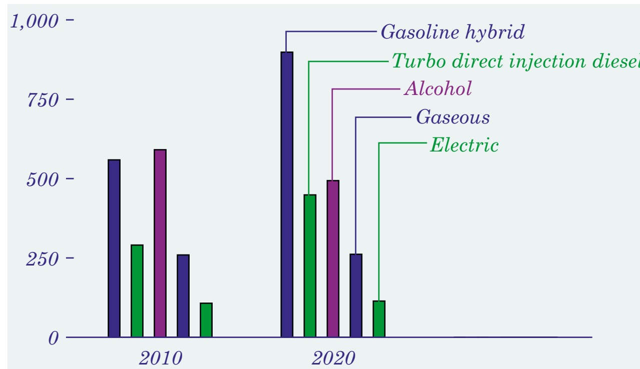
New automobile fuel economy is projected to reach approximately 31.6 miles per gallon by 2020, as a result of advances in fuel-saving technologies (Figure 57). Three of the most promising are advanced drag reduction, variable valve timing, and extension of four valve per cylinder technology to six-cylinder engines, each of which would provide between 7 and 10 percent higher fuel economy. Advanced drag reduction reduces air resistance over the vehicle; variable valve timing optimizes the timing of air intake into the cylinder with the spark ignition during combustion; and increasing the number of valves on the cylinder improves efficiency through more complete combustion of fuel in the engine.

It is more difficult for fuel-saving technology to penetrate the new truck market because of the higher marginal cost of the technologies; however, several technologies can increase fuel economy significantly, including advanced low-resistance tires (3 percent), advanced drag reduction (10 percent), and advanced low-emission high-efficiency diesel engines (10 percent). These technologies are anticipated to penetrate the heavy-duty truck market by 2020. Advanced technology penetration is projected to increase new freight truck fuel efficiency from 6.0 miles per gallon to 7.1 miles per gallon between 1998 and 2020.

New aircraft fuel efficiencies are projected to increase by more than 18 percent from 1998 levels by 2020. Ultra-high-bypass engine technology can potentially increase fuel efficiency by 10 percent, and increased use of weight-reducing materials may contribute up to a 15-percent improvement.

Advanced Technologies Could Reach Nearly 15 Percent of Sales by 2020

Figure 58. Advanced technology light-duty vehicle sales by fuel type, 2010 and 2020 (thousand vehicles sold)



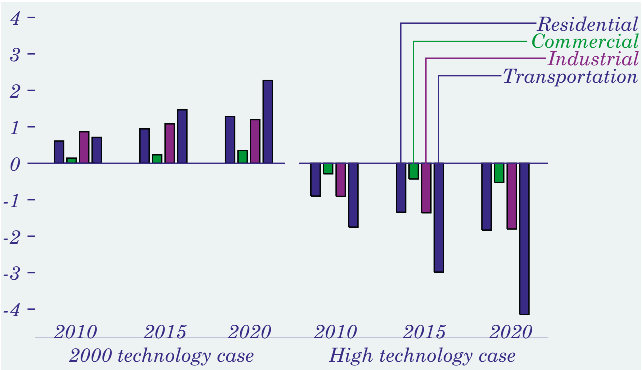
Advanced technology vehicles, representing automotive technologies that use alternative fuels or require advanced nonconventional engine technology, are projected to exceed 2.2 million vehicle sales or 14.6 percent of total light-duty vehicle sales by 2020 (Figure 58).

Gasoline hybrid electric vehicles, which will be introduced into the U.S. market by two manufacturers in 2000, are anticipated to lead advanced technology vehicle sales with almost 900,000 units by 2020. Both turbo direct injection diesels and alcohol flexible-fueled vehicles are expected to sell well in the personal vehicle market, reaching approximately 450,000 to 494,000 vehicle sales by 2020. All three of these advanced technologies will initially sell for less than $3,000 above an equivalent gasoline vehicle, but only the gasoline hybrid and the turbo direct injection diesel can achieve more than 35 to 45 percent better fuel economy than a comparable gasoline vehicle and vehicle ranges that exceed 600 miles.

About 68 percent of advanced technology sales are a result of Federal and State mandates for either fuel economy standards, emissions programs, or energy policy regulations. Alcohol flexible-fueled vehicles are currently being sold by manufacturers in order to receive fuel economy credits to comply with Corporate Average Fuel Economy regulations. The majority of the gasoline hybrid and electric vehicle sales will result from compliance with Low-Emission Vehicle programs in California, New York, and Massachusetts, which currently permit zero-emission vehicle credits for advanced technologies.

Alternative Cases Analyze Effects of Advances in Technology

Figure 59. Variation from reference case primary energy use by sector in two alternative cases, 2010, 2015, and 2020 (quadrillion Btu)



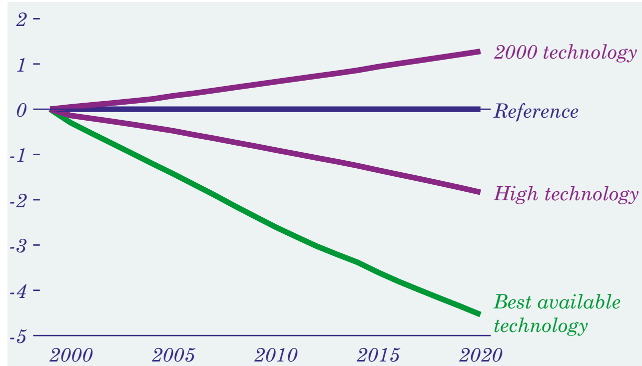
The availability and market penetration of new, more efficient technologies are uncertain. Alternative cases for each sector, based on a range of assumptions about technological progress, show the effects of these assumptions (Figure 59). The alternative cases assume that current equipment and building standards are met but do not include feedback effects on energy prices or on economic growth.

For the residential and commercial sectors, the 2000 technology case holds equipment and building shell efficiencies at 2000 levels. The best available technology case assumes that the most energy-efficient equipment and best residential building shells available are chosen for new construction each year regardless of cost, and that efficiencies of existing residential and all commercial building shells improve from their reference case levels. The high technology case assumes earlier availability, lower costs, and higher efficiencies for more advanced technologies than in the reference case.

The 2000 technology cases for the industrial and transportation sectors and the high technology case for the industrial sector use the same assumptions as the buildings sector cases. The high transportation technology case includes lower costs for advanced technologies and improved efficiencies, comparable to those assumed in a Department of Energy (DOE) interlaboratory study for air, rail, and marine travel and provided by the DOE Office of Energy Efficiency and Renewable Energy and American Council for an Energy-Efficient Economy for light-duty vehicles and by Argonne National Laboratory for freight trucks [*63*].

Advanced Technologies Could Reduce Residential Energy Use by 20 Percent

Figure 60. Variation from reference case primary residential energy use in three alternative cases, 1999-2020 (quadrillion Btu)



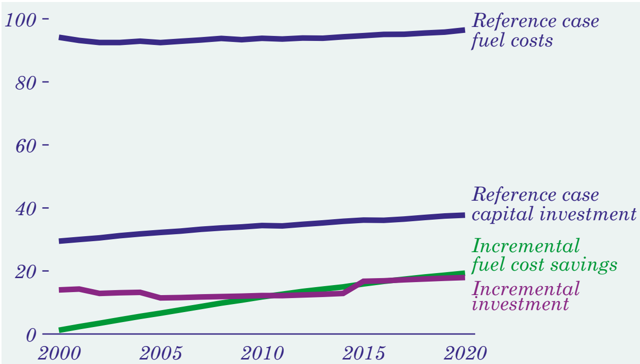
The *AEO2000* reference case forecast includes the projected effects of several different policies aimed at increasing residential end-use efficiency. Examples include minimum efficiency standards and voluntary energy savings programs designed to promote energy efficiency through innovations in manufacturing, building, and mortgage financing. In the 2000 technology case, which assumes no further increases in the efficiency of equipment or building shells beyond that available in 2000, 5.6 percent more energy would be required in 2020 (Figure 60).

In the best available technology case, assuming that the most energy-efficient technology considered is always chosen regardless of cost, energy use is 19.7 percent lower than in the reference case in 2020, and household primary energy use is 24.0 percent lower than in the 2000 technology case in 2020.

The high technology case does not constrain consumer choices. Instead, the most energy-efficient technologies are assumed to be available earlier, with lower costs and higher efficiencies. The consumer discount rates used to determine the purchased efficiency of all residential appliances in the high technology case do not vary from those used in the reference case; that is, consumers value efficiency equally across the two cases. Energy savings in this case relative to the reference case reach 8.0 percent in 2020; however, the savings are not as great as those in the best available technology case.

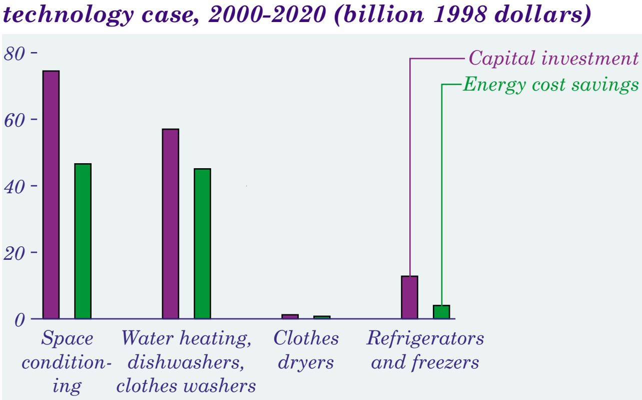
High Residential Energy Savings Would Require High Investment

Figure 61. Cost and investment changes for selected residential appliances in the best available technology case, 2000-2020 (billion 1998 dollars)



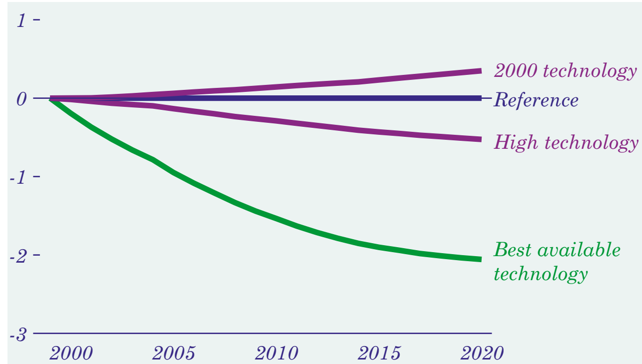
In the best available technology case, which requires the purchase of the most efficient equipment available, residential energy expenditures are lower but capital investment costs are higher (Figures 61 and 62). This case captures the effects of installing the most efficient (usually the most expensive) equipment at reference case turnover rates, regardless of economic considerations. An incremental investment of $145 billion [*64*] reduces residential delivered energy use by nearly 18 quadrillion Btu—saving consumers more than $96 billion in energy expenditures—through 2020. Water heating and space conditioning show the greatest potential for savings, but at a substantial investment cost. In place of conventional technologies (such as electric resistance water heaters), natural gas and electric heat pump water heaters and horizontal-axis washing machines can substantially cut the amount of energy needed to provide hot water services.

Figure 62. Present value of investment and savings for residential appliances in the best available technology case, 2000-2020 (billion 1998 dollars)



Advanced Technologies Could Reduce Commercial Energy Use by 10 Percent

Figure 63. Variation from reference case primary commercial energy use in three alternative cases, 1999-2020 (quadrillion Btu)

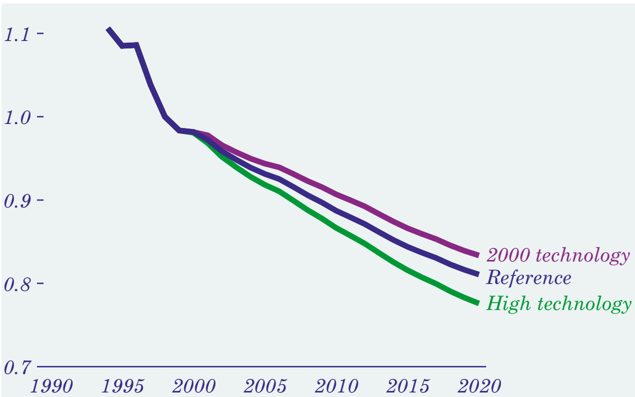


The *AEO2000* reference case incorporates efficiency improvements for commercial equipment and building shells, contributing to a 0.1-percent annual decline in commercial energy intensity over the forecast. The 2000 technology case assumes that future equipment and building shells will be no more efficient than those available in 2000. The high technology case assumes earlier availability, lower costs, and higher efficiencies for more advanced equipment than in the reference case and more rapid improvement in building shells. The best available technology case assumes that only the most efficient technologies will be chosen, regardless of cost, and that building shells will improve at the rate assumed in the high technology case.

Energy use in the 2000 technology case is 1.9 percent higher than in the reference case by 2020 (Figure 63), with no change in commercial primary energy intensity. In the high technology case there is an additional 2.9-percent energy savings in 2020, and primary energy intensity falls by 0.2 percent a year from 1998 to 2020. Allowing the purchase of only the most efficient equipment in the best available technology case yields energy use that is 11.3 percent lower than energy use in the reference case by 2020. Commercial primary energy intensity declines more rapidly in this case than in the high technology case, by 0.6 percent a year. More optimistic assumptions result in additional energy savings from renewable technologies, as well as those using conventional fuels. Solar photovoltaic systems generate 9 percent more electricity in the high technology and best technology cases than in the reference case.

Alternative Technology Cases Show Range of Industrial Efficiency Gains

Figure 64. Industrial primary energy intensity in two alternative cases, 1994-2020 (index, 1998 = 1)



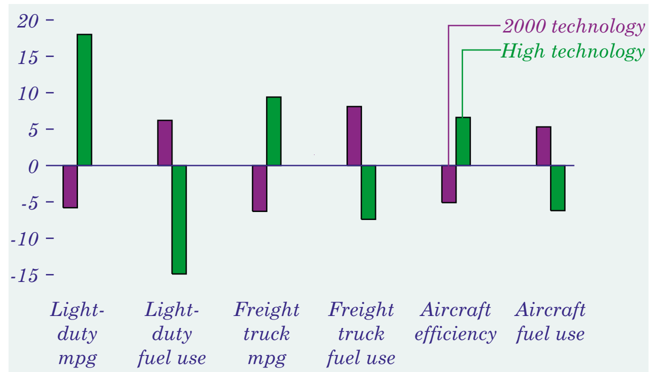
Projected efficiency gains in both energy-intensive and non-energy-intensive industries provide improvement in energy intensity. The growth in machinery and equipment production, driven primarily by investment and export-related demand, is a key factor: these less energy-intensive industries grow 56 percent faster than the industrial average in the reference case (2.9 percent vs. 1.8 percent a year).

In the high technology case, 1.8 quadrillion Btu less energy is used in 2020 than for the same level of output in the reference case. Industrial primary energy intensity declines by 1.1 percent a year through 2020 in this case, compared with a 1.0-percent annual decline in the reference case (Figure 64). While the individual industry intensities decline about twice as rapidly in the high technology case as in the reference case, the aggregate intensity is not as strongly affected, because the composition of industrial output is the same in the two cases.

In the 2000 technology case, industry consumes 1.2 quadrillion Btu more energy in 2020 than in the reference case. Energy efficiency remains at the level achieved new plants in 2000, but average efficiency still improves as old plants are retired. Aggregate industrial energy intensity declines by 0.8 percent a year because of reduced efficiency gains and changes in industrial structure. The composition of industrial output accounts for 87 percent of the change in aggregate industrial energy intensity in the 2000 technology case, compared with 76 percent in the reference case.

Vehicle Technology Improvements Would Lower Carbon Emissions

Figure 65. Changes in key components of the transportation sector in two alternative cases, 2020 (percent change from reference case)



The transportation high technology case assumes lower costs, higher marginal efficiencies, and earlier introduction dates for new technologies. Demand is 4.2 quadrillion Btu (11 percent) lower in 2020 than in the reference case, reducing carbon emissions by 80 million metric tons. About 75 percent of the demand reduction in 2020 is for light-duty vehicles, where demand is reduced by 3.1 quadrillion Btu in 2020 as a result of advances in conventional technologies and in vehicle attributes for advanced technologies, which raise the average efficiency of the light-duty vehicle fleet to 24.3 miles per gallon, compared with 20.6 miles per gallon in the reference case (Figure 65).

In the high technology case, energy demand for freight trucks is reduced by 0.4 quadrillion Btu in 2020 relative to the reference case, as advanced technologies increase freight truck stock efficiency by 9.4 percent. Advanced aircraft technologies also reduce energy demand by 0.4 quadrillion Btu in 2020 in the high technology case, improving aircraft efficiency by 6.6 percent above the reference case.

In the 2000 technology case, with new technology efficiencies fixed at 2000 levels, efficiency improvements result only from stock turnover. In 2020, total transportation demand is 2.3 quadrillion Btu (6 percent) higher than in the reference case, and carbon emissions are 44 million metric tons higher. The fuel economy for new light-duty vehicles is 24.2 miles per gallon in 2020 in the 2000 technology case, 2.3 miles per gallon lower than in the reference case.